

Horizontal Growth and *In Situ* Assembly of Oriented Zinc Oxide Nanowires

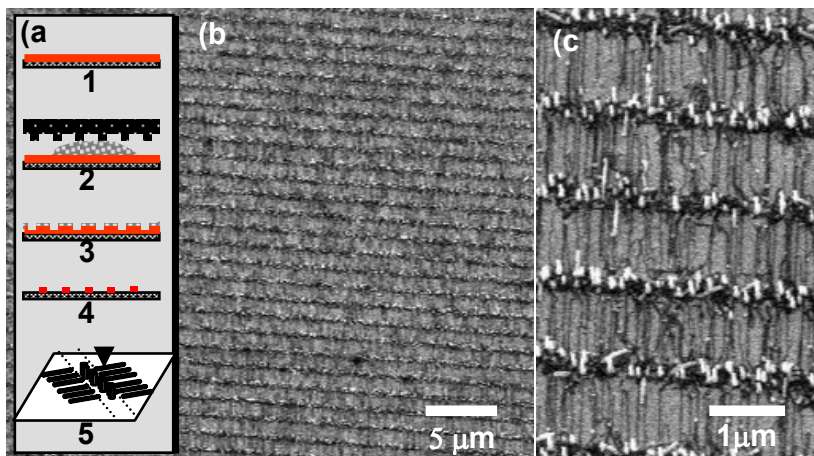
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Research in the area of nanoscopic materials has the potential for providing new classes of materials with performance and functionality not achievable by systems on large length scales. In the field of photonics, work is underway in the development of nanoscale light sources and detectors that are capable of operation at the single photon level. When coupled with the ability to manipulate and assemble these elements into hierarchical structures, nanodevices capable of performing sophisticated functions such as quantitative chemical measurement will be realized. Our recent efforts in this area have focused on developing methods for directed growth and assembly of semiconducting nanowires (NW).

CSTL develops an approach that promotes the horizontal growth, *in situ* alignment, and predictable positioning of ZnO nanowires (NWs), allowing for the large-scale production and assembly of ZnO NWs and NW arrays.

In the majority of semiconductor NW syntheses schemes, a thin catalyst film is used as the nucleation site/media for growth of NWs, resulting in standing NWs with diameters ranging from 20 nm to 120 nm. However, this approach has limited control over the diameter of the NWs making diameters smaller than 10 nm difficult to prepare. Perhaps more important for most device applications, NWs need to be assembled and aligned in the plane of the surface. To this end, we have developed a new technique for the growth of semiconductor NWs, which overcomes the limitations stated above. Using our approach, single-crystal NWs with adjustable diameters between 1 nm to 20 nm are grown horizontally (in the plane of the surface) along crystallographic directions on an *a*-plane sapphire surface.

a) Steps 1 through 4 show the preparation of Au lines as catalyst. Step 5 shows an Au line after growth of NWs. b) and c) Sapphire surface after growth of NWs. Large-scale assembly of NWs is seen in low (b) and high magnification images (c).



Our studies show that the crucial requirements for horizontal growth of NWs are the size of and the spacing between Au catalyst nanodroplets. To fulfill these geometric requirements, we have used thin Au lines (width < 200 nm) and/or lines of Au nanoparticles as nucleation sites for NWs growth (Figure 1a). Using a vapor-phase transport process at high temperature, each nanoparticle in the Au lines nucleates ZnO formation and becomes an NW. The figure is an example of the resulting oriented NW arrays formed using this procedure.

The methodology developed at NIST will provide an inexpensive and straightforward approach to the synthesis of semiconducting nanodevices (emitters and detectors) with multiple functionalities that can be integrated to form state-of-the-art measurement systems

B. Nikoobakht, C.A. Michaels, S.J. Stranick, M.D. Vaudin, "Horizontal Growth and *in situ* Assembly of Oriented Zinc Oxide Nanowires", Appl. Phys. Lett. 85, 3244 (2004).

This research has focused on the growth and manipulation of semiconductor ZnO nanowires. These methodologies are now being implemented in the fabrication of heterostructured (ZnO/GaN) NWs for use as nano-emitting sources (laser diodes) and nano-detectors (photodiodes) with emphasis on optical properties and performance suited for applications in sensing and spectrochemical analysis